Athena as an Observatory in the late 2020s

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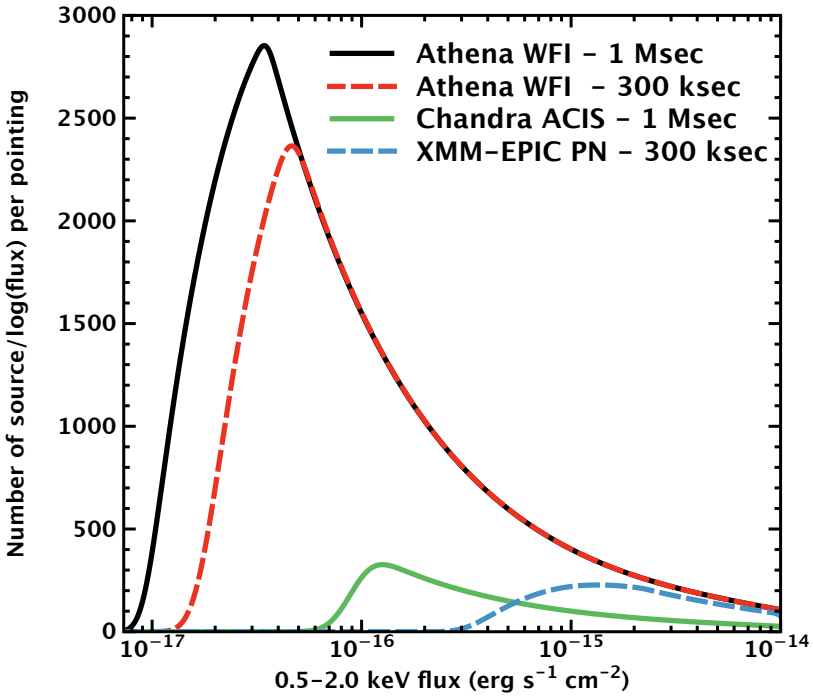
Athena beyond The Hot and Energetic Universe

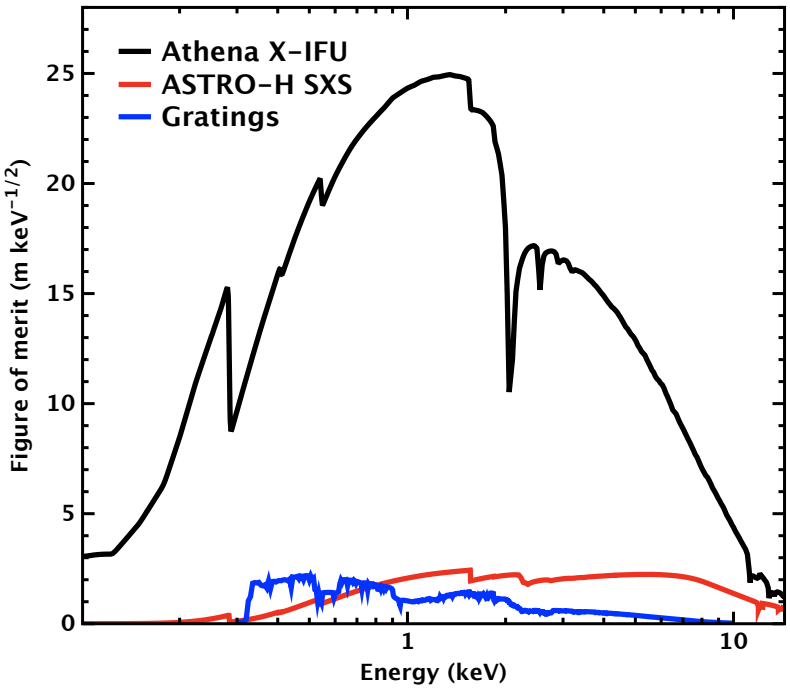
- Athena will address a very challenging and timely set of science objectives on the Hot and Energetic Universe
- But also a large number of **observatory science** capabilities:
  - Solar system planet atmospheres, probing the solar wind
  - Exoplanets: interaction of stellar activity with planets
  - Stellar physics: YSOs, brown dwarfs, massive stars
  - Supernovae & Supernova remnants
  - Stellar end points: neutron stars, magnetars, white dwarfs etc
  - Sgr A*
  - Interstellar medium
  - High-energy transients
- **And a great deal of science that we cannot foresee today**

Athena performance

Survey speed

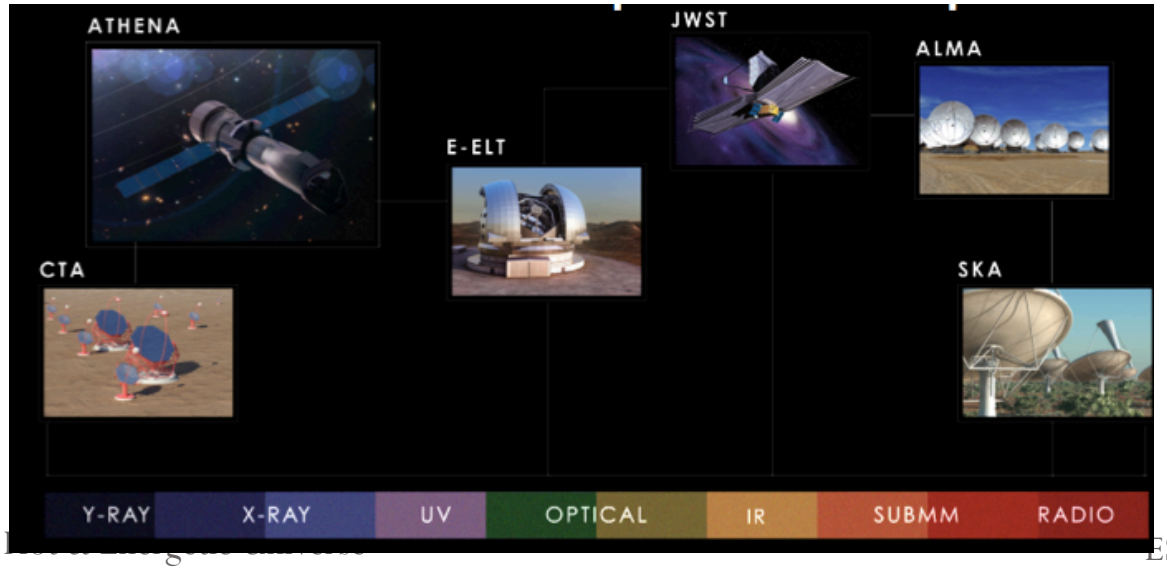


Spectroscopic grasp



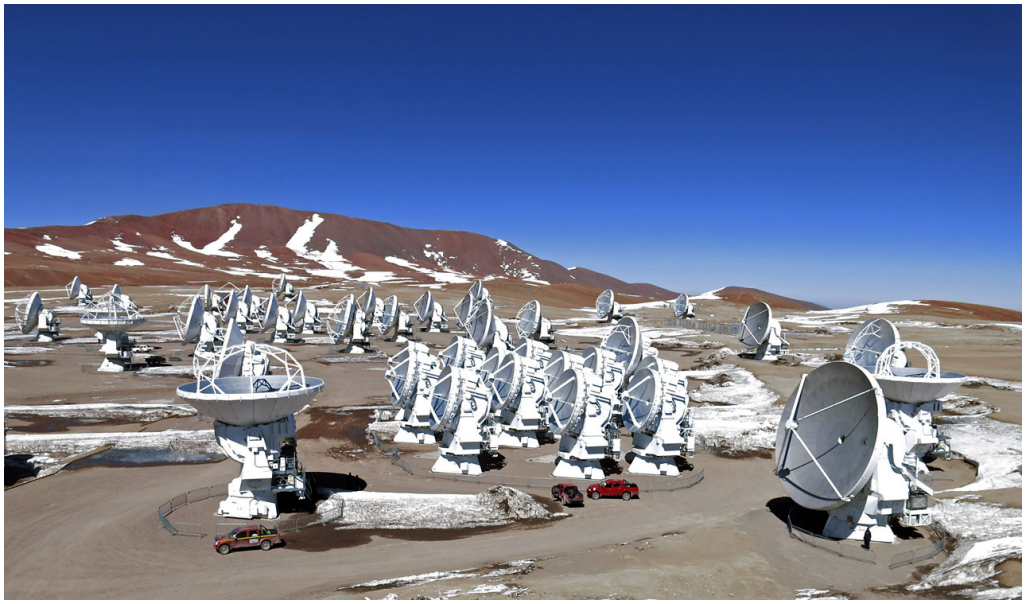
The (European) astronomical landscape in the late 2020s

- ASTRONET just released an updated Science Vision and Roadmap
- Major elements:
  - In place: ALMA
  - Approved/in development: JWST, E-ELT, Euclid, Athena
  - In the horizon: CTA, SKA
  - Other: LSST, WFIRST



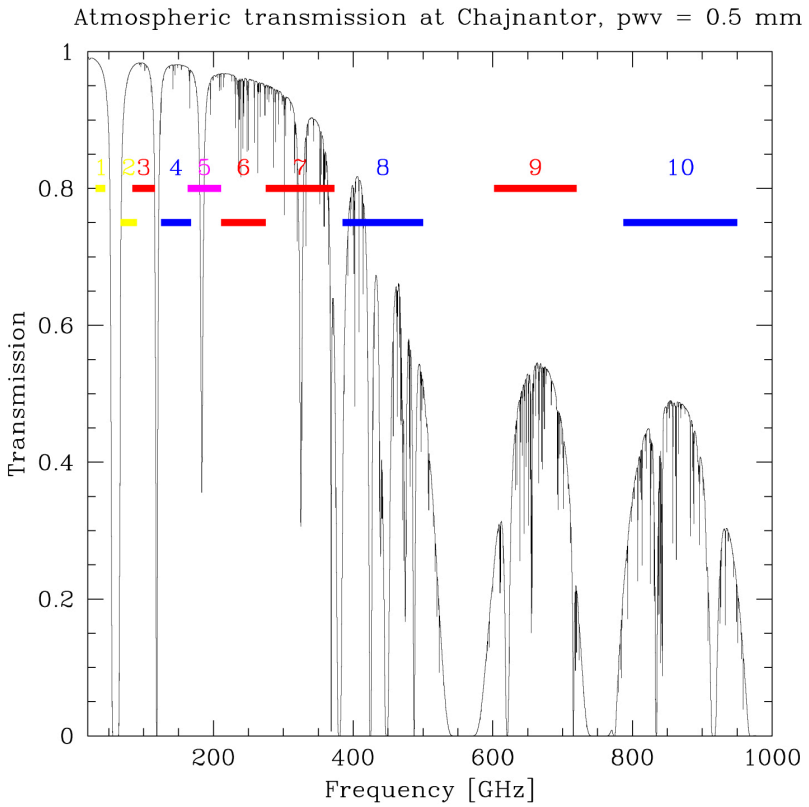
ALMA: The global (sub)mm facility

- Largest (sub)mm radio interferometer, in Chajnantor (Chile)
  - 66 antennas, at 5000 m, 0.4-3 mm, baselines up to 15 km
- Partnership between
  - ESO (37.5%)
  - NSF/AUI/NRAO (37.5%)
  - NINS/NAOJ (25%)
  - In cooperation with Chile
- Operational since 9/2011



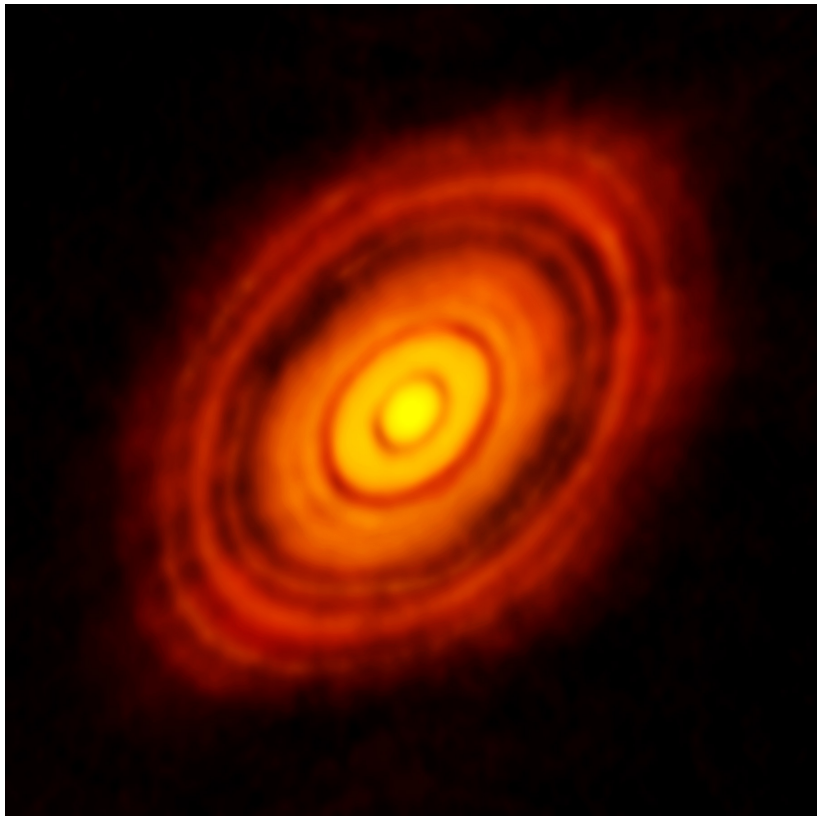
ALMA bands & performance

- Bands from 0.4mm to 3 mm
- Spatial resolution
  - 0.7”-4.8” in compact config
  - 6-37 mas in extended config
- Primary beam ~21”
- Spectral resolution: limited by 7680 channels and 8 GHz bandwidth.
  - 1 km/s easy to achieve
- Sensitivity: enormous

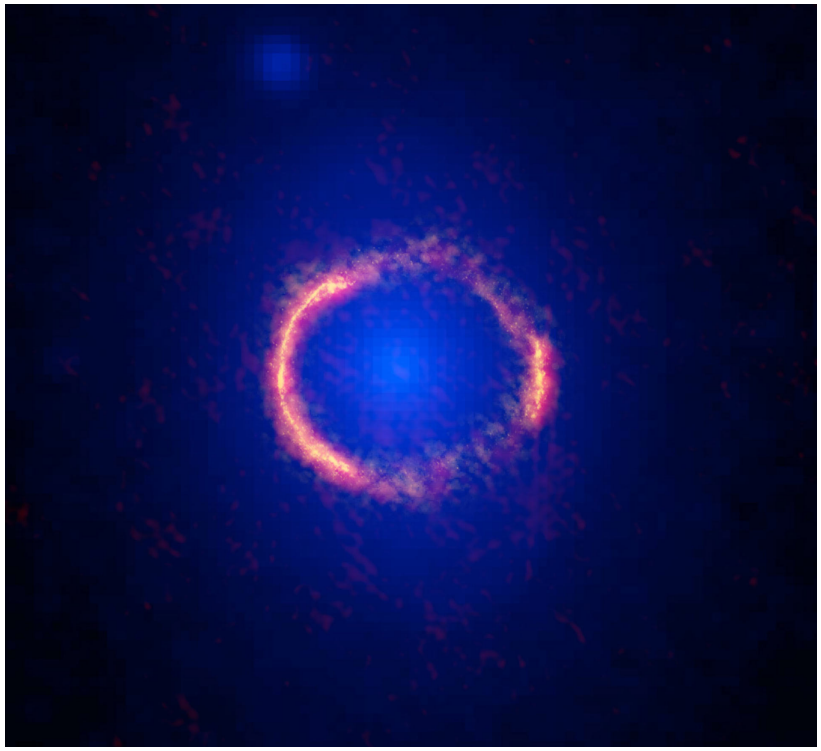


Amazing ALMA science

HL Tau proto-planetary disk



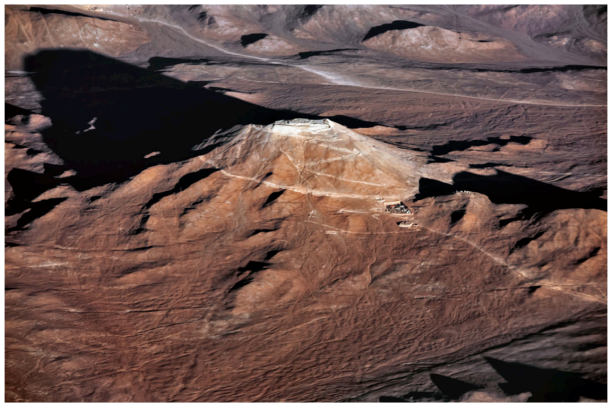
Einstein ring at z=3



European Extremely Large Telescope (E-ELT)

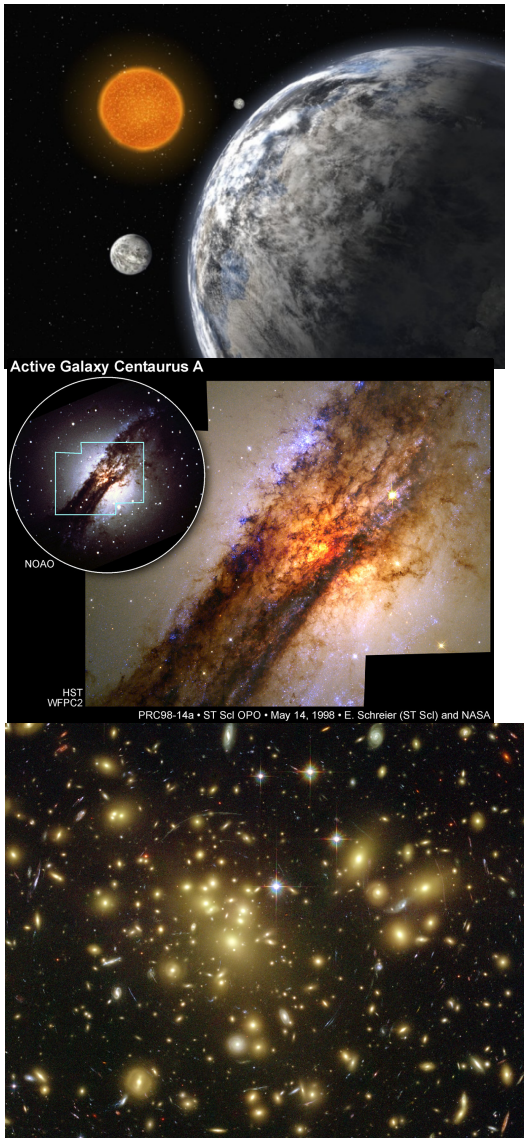
The E-ELT project

- Telescope with 39.3m segmented mirror, NIR-optimized, built-in adaptive optics
- To be erected in Cerro Armazones, part of the Paranal complex
- Programme is approved, construction started in 2014. Phase 1 authorised:
  - 3 instruments funded: MICADO/MAORY, HARMONI & METIS
  - ELT-MOS & ELT-HIRES studies funded
  - Inner mirror rings not filled initially
- First light expected late 2024.



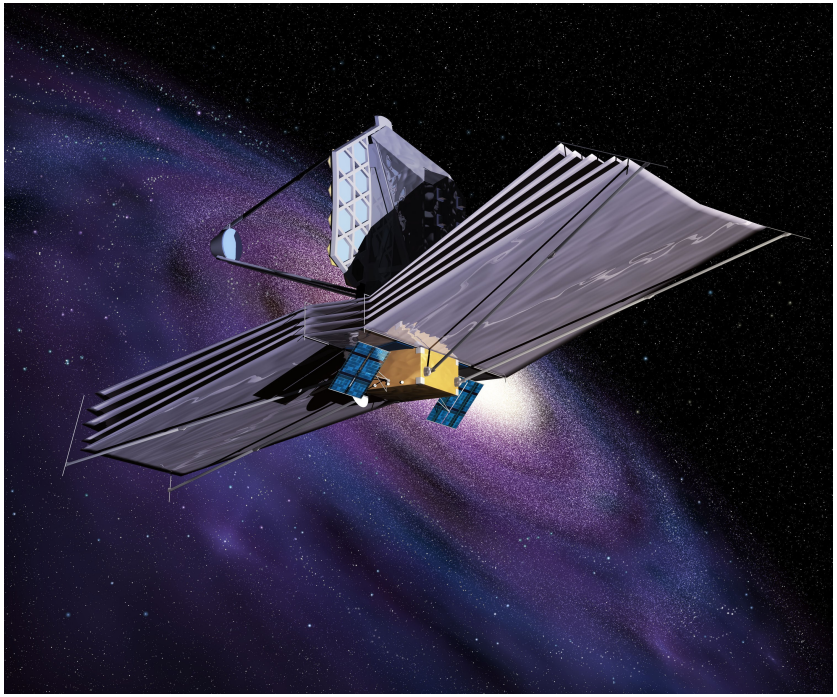
E-ELT science objectives

- Stars & planets
  - Find & characterise exo-Earths
  - Circumstellar disks
  - Stellar clusters
- Stars & galaxies
  - Stellar pops in external galaxies
  - SMBH masses in nearby galaxies
- Galaxies & Cosmology
  - First (NIR) light in the Universe
  - Chemical evolution of the Universe
  - Real-time measurement of the accelerating Universe



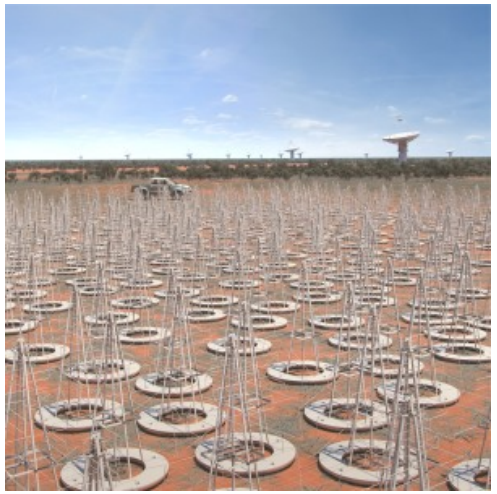
JWST (2018+)

- Science objectives:
  - End of dark ages: first light & reionisation
  - Assembly of galaxies
  - Birth of stars and protoplanetary systems
  - Planetary systems & life
- Instruments
  - NIRcam (0.6-5.0 μ m, 2'x2')
  - NIRSpec (0.7-5.0 μ m, 3')
  - MIRI (5-28 μ m, 100" img, 7" spec)
  - NIRISS (0.8-2.2 μ m, 2.2')



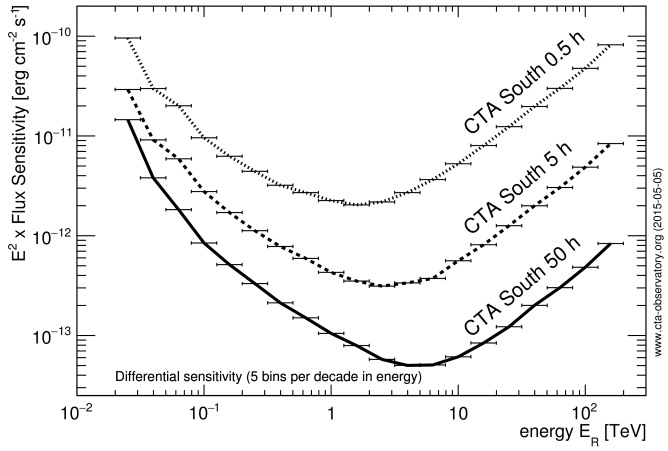
SKA – Square Kilometre Array

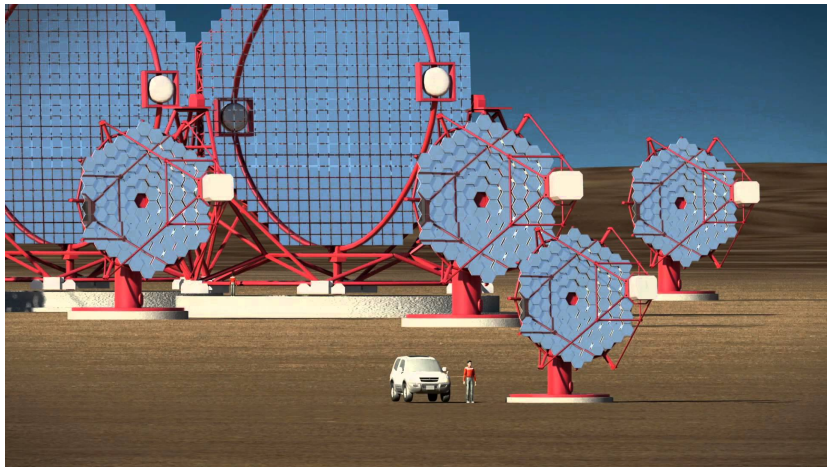
- Science objectives:
  - Galaxy evolution, cosmology & dark energy
  - Strong gravity from BHs and pulsars
  - Cosmic magnetism
  - Dark ages
  - The cradle of life
- SKA1 approved (cost cap ~650 M€):
  - SKA1-MID (0.35-14 GHz, 200 dishes) South Africa
  - SKA1-LOW (50-350 MHz, 500 stations) Australia
  - Construction 2018-2023, early science 2020+



CTA – Cerenkov Telescope Array

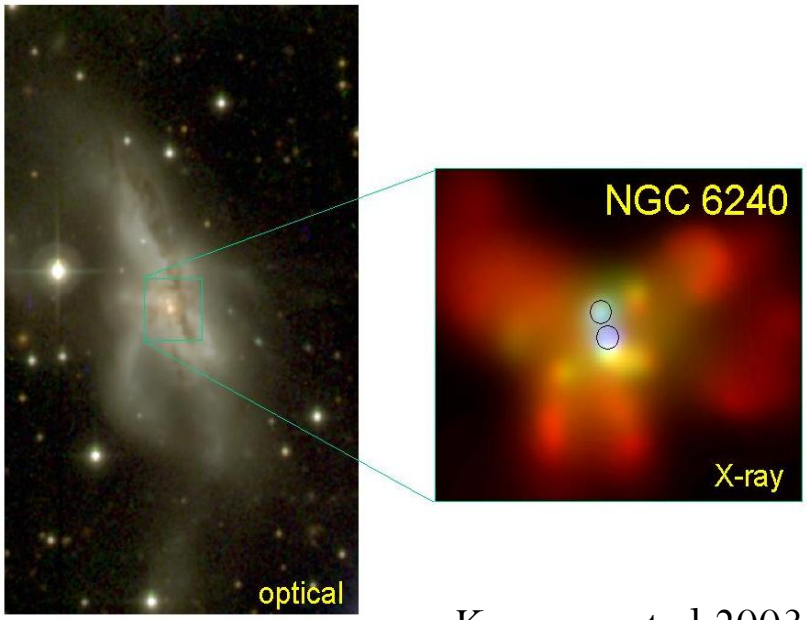
- **First** Atmospheric Cerenkov telescope **γ-ray Observatory**
- Sites: La Palma (Spain) & ESO Paranal (Chile)
- Construction 2018-2023
- Dynamic range: 0.05-50 TeV
- Science objectives:
  - Origin of cosmic rays
  - Black Holes, jets and Extragalactic Bakcground Light/SF history
  - The nature of Dark Matter & other questions in fundamental physics



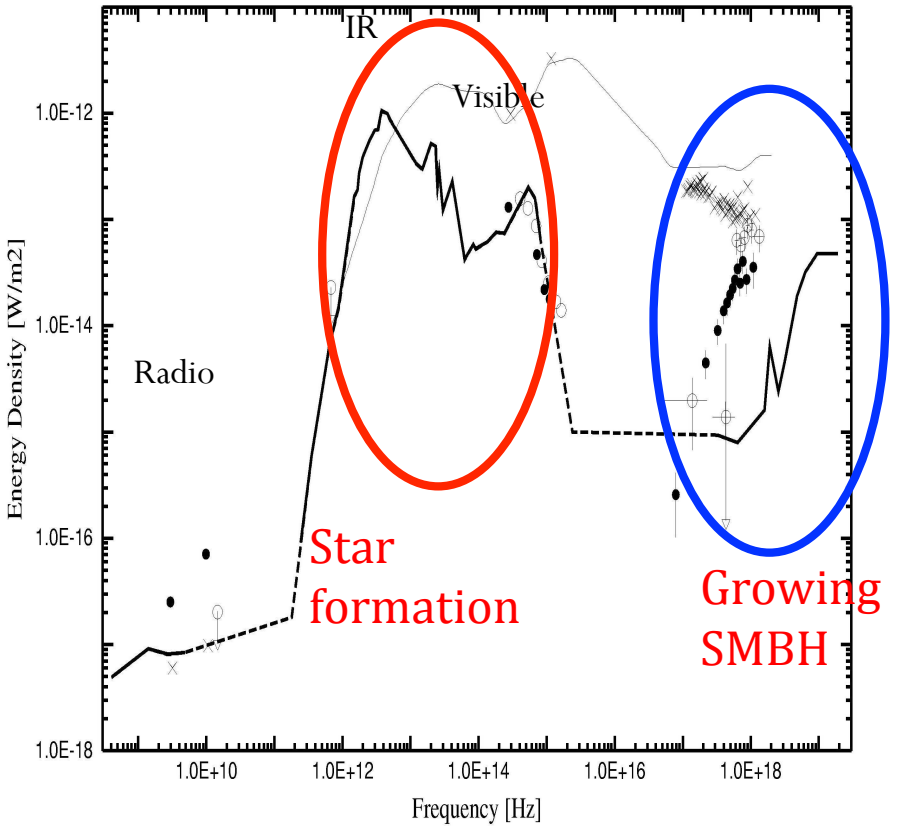


Multi-wavelength view of galaxies

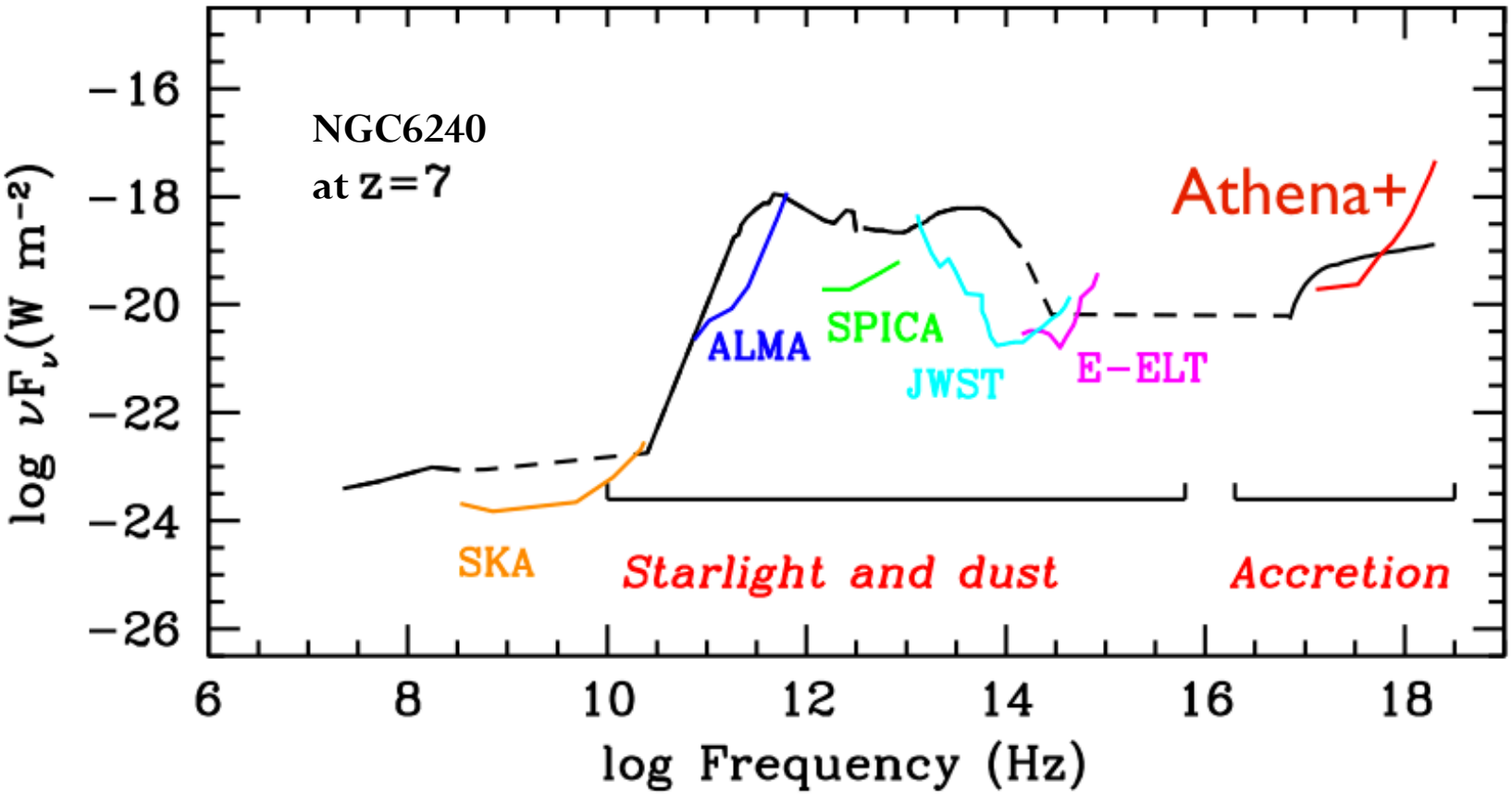
NGC6240: a SF galaxy with a double AGN



Komossa et al 2003



Synergetic look at early galaxies

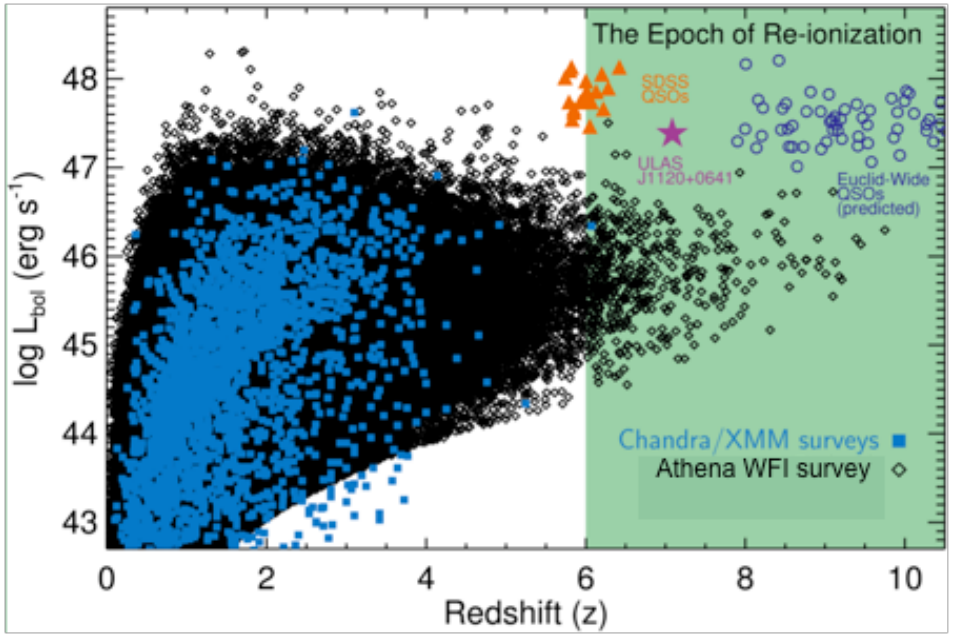


Developing synergies

- **Synergy: Two or more agents working together to produce a result not obtainable by any of the agents independently** (Source: wikipedia)
- Synergies between astronomical infrastructures are to be expected naturally: one sky, same teams
- Scientific synergies, in two flavours (and in between):
  - **Operational**: The use of other facilities is needed to achieve the own scientific goals. **Athena has several of those**
  - **Added value**: Using several facilities in conjunction leads to science added value beyond the individual goals. **Need to be identified and developed.**

High-z AGN, an example of Athena "Operational" synergy

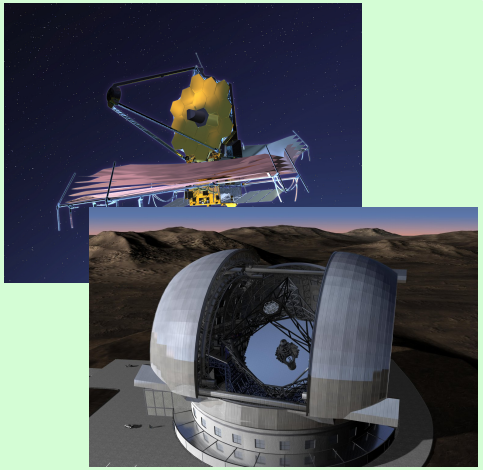
- "Needle in the haystack": finding z>6 AGN in multi-tiered X-ray surveys:
  - Multi- λ photometry
  - Opt/NIR Spectroscopy
- **This needs to be programmed carefully, and not pretend that ancillary observations will be gracefully granted.**



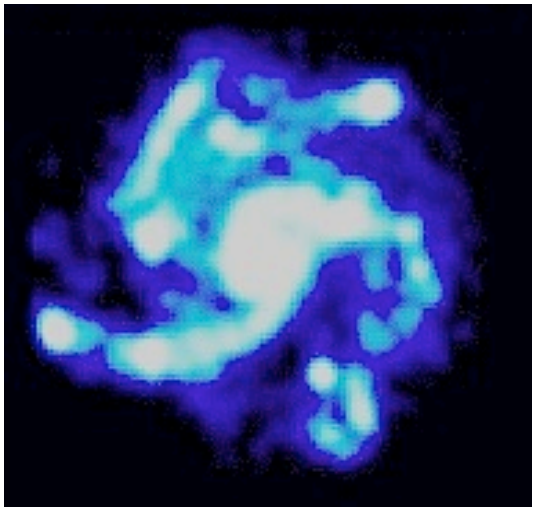
Examples of **existing** scientific synergies, outstanding outcome

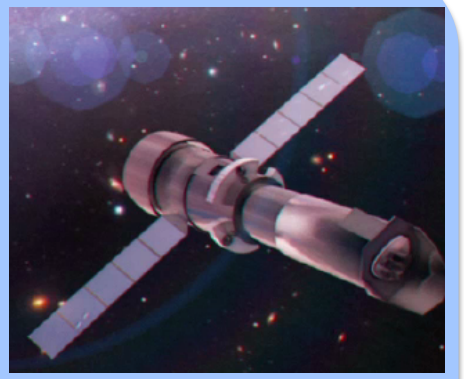
- Cluster evolution up to z~1 (Planck + XMM-Newton)
- Galaxy/AGN evolution (HST + Opt/NIR ground + X-ray) in selected cosmological fields.
- AGN feedback through winds & outflows (XMM-Newton + Herschel/ALMA)
- GRBs (Swift/Agile + everything)
- Molecular astrophysics (ISO/Spitzer/Herschel + ALMA + MIR instruments on ground telescopes + Rosetta)
- …
- (Do your own ADS search and you will be surprised!)

Witnessing galaxy-SMBH co-evolution at high z



Dynamical masses of z<0.5 SMBH
Stellar masses & SFR
Redshifts & morphologies



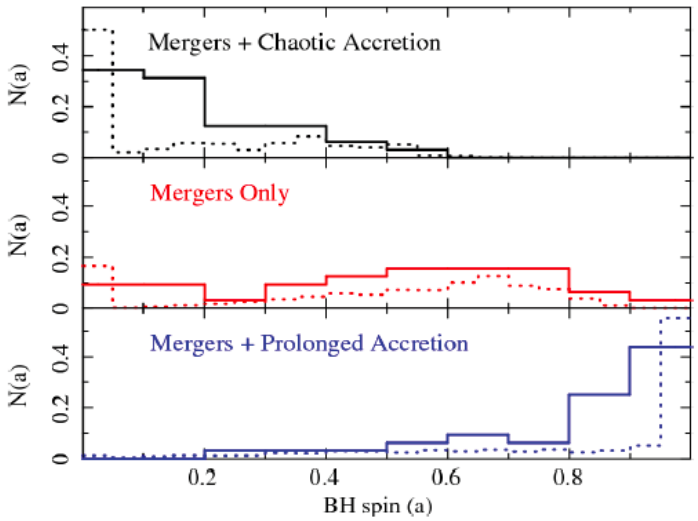


Unveal obscured AGN
Quantify AGN feedback

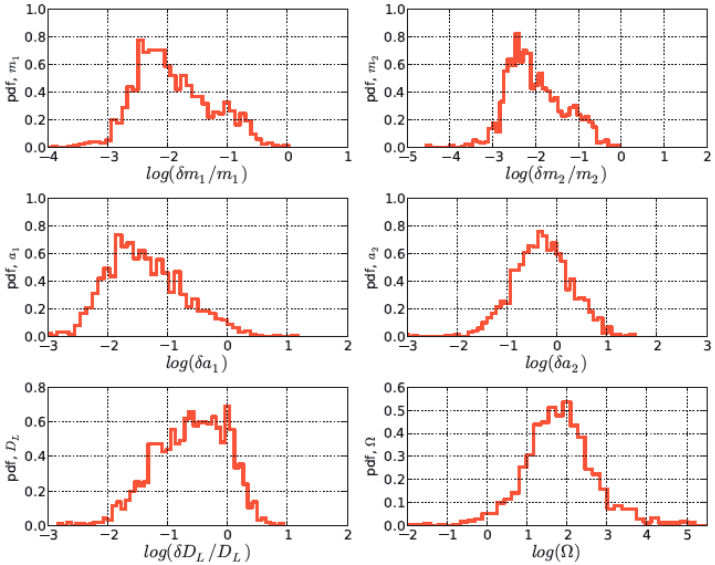
Cold gas & dust masses
Molecular outflows

SMBH spins: mergers vs accretion

X-ray Fe line profiles

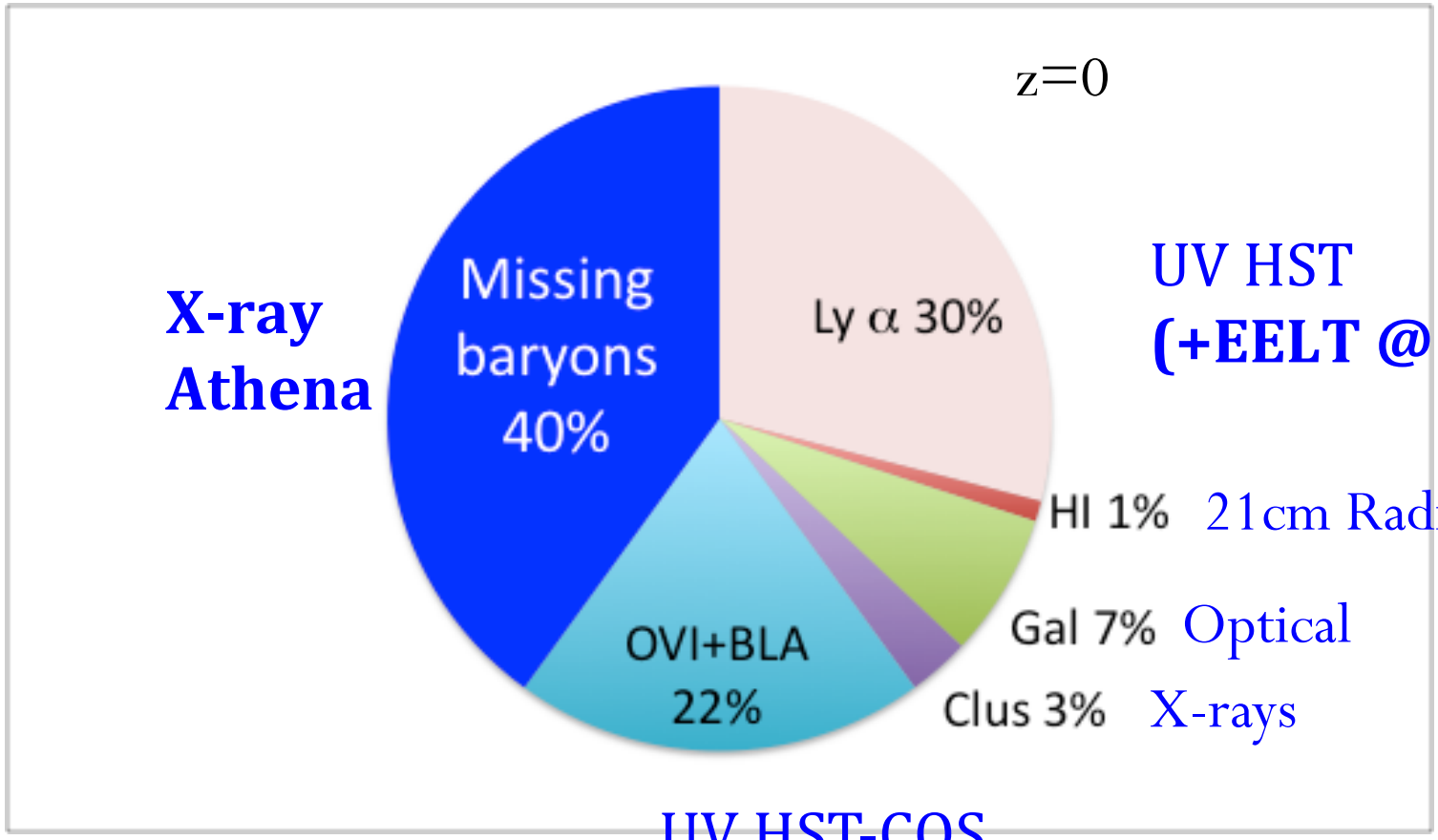


GW measurements



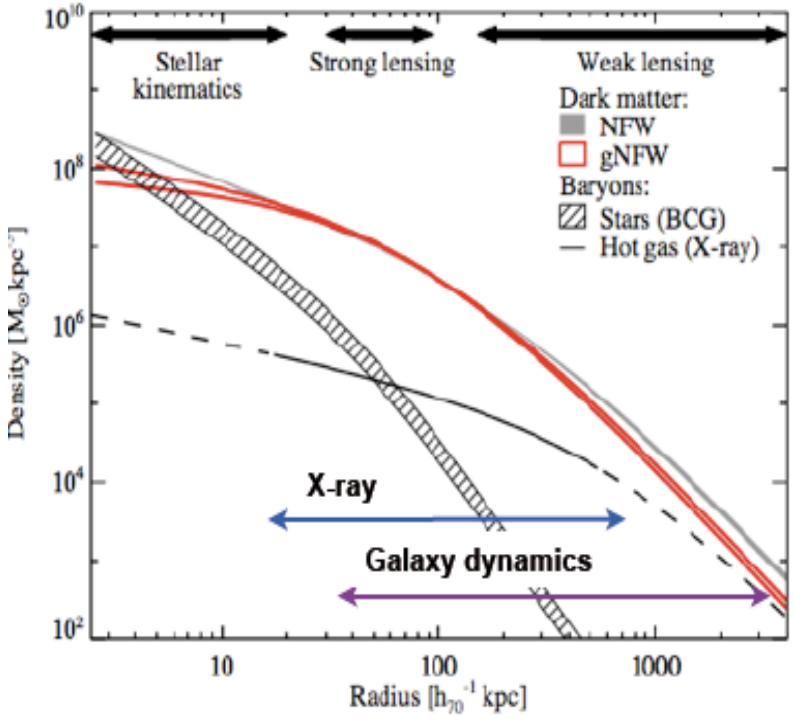
+ also from radio jets (SKA)

The cosmic baryon budget



Large Scale Structure: DM and baryons in clusters

- Mass measurements from lensing (Euclid, E-ELT) & gas hydrodynamics (Athena)
  - Measure turbulence and gas bulk motions (Athena)
- Dark Matter profile and accurate measurement of gas to mass ratio



And much more...

- Solar system planetary atmospheres (+"in situ" probes)
- Multi-messenger observations
  - CR & gamma-rays (+CTA)
  - GW signals, followed up by multi-wavelength observations, including X-rays (+VIRGO, LIGO, eLISA)
- SgrA* (+EHT, VLTI/Gravity)
- Chemical evolution (+E-ELT, ALMA)
- The transient sky (+LSST, +GRB missions)
- …

Outlook

- Athena will be the only X-ray observatory in the late 2020s:
  - Qualitative step forward with respect to its predecessors
  - Capable of impacting all corners of Astrophysics
- Its expected performances are well matched to other contemporary facilities
  - Part of a family of powerful observatories across the spectrum
- Synergetic work of Athena with other facilities:
  - Needed to achieve science objectives (need being planned)
  - Of high added value (need being identified and developed)
- **We need to work on both types of synergies**